

## **Impact of Foot Type on Cost of Lower Extremity Injury**

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14. ABSTRACT <b>The primary purpose was to determine the relationship between foot type and medical costs associated with lower extremity MSI. An additional purpose was to describe the utilization of healthcare and costs. Participants (n=688; M=392, F=276; age 30.1±7.4 years, BMI 25.8±3.3 kg/m2) were prosepctively followed for 31 months. The Foot Posture Index (FPI-6) quantified static foot posture. Medical costs, diagnostic codes, and relative value units (RVUs) associated with healthcare visits were acquired from the military healthcare database. Univariate ANOVAs were performed to compare costs, body regions, and static foot posture. Three hundred and thirty six (50.3%) of 668 participants sought medical care for lower extremity MSI, totalling 2,112 medical visits and a cost of \$436,965. Costs varied by foot type for injuries below the knee (p&lt;.05). Post hoc analysis demonstrated that the extreme pronated foot type resulted in increased RVUs for leg injuries (p=.02) and increased visits for injuries from the knee to the foot (p=.02), and in the leg region (p=.003) when compared to the normal foot type. Pronated feet, as assessed by the FPI-6, were associated with significantly higher injury costs and healthcare utilization for injuries from the knee to the foot, especially in the leg and foot regions.</b>					
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**ABSTRACT**

**Purpose/Hypothesis:** Lower extremity musculoskeletal injury (MSI) affects over 720,000 service members annually. Ankle and foot injuries (including stress fractures) have accounted for approximately 40% of these injuries, and the most common complaint during an infantry road march under load was overuse related foot pain. Although risk factors for MSI are multifactorial, good evidence suggests that foot type serves as an intrinsic risk factor for lower extremity MSI. However, information related to the impact of foot type on the medical costs of lower extremity MSI in the military is limited. The primary purpose of this study was to determine the relationship between foot type and medical costs associated with lower extremity MSI. An additional purpose was to describe the utilization of healthcare and which lower extremity regions incurred these costs.

**Subjects:** One thousand healthy U.S. military healthcare beneficiaries were enrolled as part of a larger study. Of those, 668 participants ( $M = 392$ ,  $F = 276$ ; age  $30.1 \pm 7.4$  years, BMI  $25.8 \pm 3.3$  kg/m<sup>2</sup>) who continued in active military service for at least 18 of the following 31 months were included in this analysis.

**Materials/Methods:** Static foot posture was quantified using the Foot Posture Index (FPI-6). Medical costs, diagnostic codes, and relative value units (RVUs) associated with healthcare visits for lower extremity MSI over the subsequent 31 month period were acquired from the military healthcare database. Healthcare utilization was categorized according to body region (lumbopelvic, knee, leg, ankle, foot, and unspecified). Univariate ANOVA and Sidak post hoc analyses were performed to compare costs, regions of injury, and static foot posture.

**Results:** Three hundred and thirty six (50.3%) of 668 participants sought medical care for lower extremity MSI during the study period, totaling 2,112 medical visits and a cost of \$436,965. Costs varied significantly by foot type for injuries below the knee ( $p < .05$ ). Post hoc analysis demonstrated that the extreme pronated foot type resulted in increased RVUs for leg injuries ( $p=.02$ ) and increased visits for injuries from the knee to the foot ( $p=.02$ ), and in the leg region ( $p=.003$ ) when compared to the normal foot type.

**Conclusions:** Pronated feet, as assessed by the FPI-6, were associated with significantly higher injury costs and healthcare utilization for injuries from the knee to the foot, especially in the leg and foot regions. Our findings are consistent with previous researchers who have found that extreme scores of the FPI-6 were associated with increased injury risk. Future research should determine if correctly identifying people with foot types susceptible to severe lower extremity MSI could help reduce future injuries and injury-related costs.

**Military Relevance:** Correctly identifying people with foot types susceptible to severe lower extremity MSI could help inform clinical decision making, reduce recurrent injuries and injury-related costs for the individual and their organization.

## **1.0 INTRODUCTION**

Musculoskeletal injuries are a common, costly problem among athletic populations. Of all reported injuries, 90% are related to physical training and sports activities.[1-3] It has been estimated that 50-80% of these injuries are related to the lower extremity and are overuse in nature.[4-8] The National Center for Injury Prevention and Control has estimated that more than 10,000 Americans seek medical treatment daily for sport, recreational activity, and exercise-related injuries.[9] The direct and indirect costs of managing these conditions are substantial. In the military, conservative figures estimate that 535,000 musculoskeletal injuries are sustained by U.S. military members annually, resulting in 25 million limited duty days and medical costs exceeding \$300 million.[10, 11] Lower extremity injuries alone account for over 48% of all injuries.[11] Strategies to prevent injury would reduce healthcare costs and help maintain a fit, ready force.

Lower extremity overuse injuries are multifactorial.[5, 12, 13] An individual's age,[13, 14] sex,[14] prior history of injury,[1, 14, 15] self-reported fitness levels,[16, 17] cigarette smoking,[18] and body weight[13, 14] have all been well documented in the literature as factors contributing to the development of these injuries. Extremes in arch height (both low and high) have been identified as risk factors for lower extremity overuse injuries [19-22] due to the altered biomechanical properties associated with them during gait.[22-26] Subjects with low arches (overpronators and those exhibiting pes planus) and high arches (underpronators and those with pes cavus) are reported to have twice the risk[27] for developing overuse injuries than those with normal arches,[26, 28] especially knee pain. Individuals with rigid, high arched feet may be at greater risk for sustaining bony ankle injuries,[26] stress fractures,[29-32] anterior knee pain,[33] and injuries involving the lateral structures of the lower extremity.[20, 22, 26, 34, 35] Those with low arched feet or who excessively pronate[36] or supinate[20, 37] may be at greater risk for medial tibial stress syndrome,[36, 38] knee pain,[33] and soft tissue overuse injuries[20, 22, 38] along the medial aspect of the lower extremity.[26] Although foot type has been linked to injury, there is controversy in the literature.[36, 37, 39]

The Foot Posture Index (FPI-6) is a relatively new clinical tool designed to provide a fast, simple, and multidimensional assessment of foot type.[40, 41] Researchers have found the FPI-6 to have moderate to good reliability,[20, 42-45] while reported level of associations between the FPI-6 and radiographic measurements of the foot vary.[44, 46] Burns et al[37] found that triathletes with a supinated foot type as assessed by the FPI-6 were 4.3 times more likely to sustain an overuse injury compared to individuals with a neutral or pronated foot type. These findings were confirmed by Cain et al[20], who found that adolescent male indoor football players with an FPI-6 composite score < 2.0 were at higher risk for injury. Additionally, researchers have found relationships between chronic heel pain and osteoarthritis of the knee and hip.[47] [48] Despite the initial evidence supporting the relationship between extreme FPI-6 composite scores and lower extremity injury risk, scant evidence is available regarding the impact of foot type on the medical costs of lower extremity MSI in the military. The primary purpose of this study was to determine the relationship between FPI-6 and medical costs associated with lower extremity MSI. An additional purpose was to describe the utilization of healthcare and which lower extremity regions incurred these costs.

## **2.0 METHODS**

### **2.1 Subjects**

This cross-sectional, prospective study is one aspect of a larger research trial, the Foot Assessment Algorithm for Soldiers in Training (FAAST study).[25] All subjects were recruited from the Department of Defense beneficiary population (active duty service members, retirees, and dependents) in San Antonio, Texas, USA. Subjects were required to be between the ages of 18 and 50 and fluent in English. All subjects had to be in good health and injury-free when foot assessment measurements were obtained, and without any significant history

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of trauma or recurrent overuse injuries to the lower extremity resulting in any gait asymmetry. Every subject gave informed consent according to the Brooke Army Medical Center Institutional Review Board. For the purposes of this study, the Defense Enrollment Eligibility Reporting Systems (DEERS) database was utilized to exclude any subjects who were not on active duty service for at least 18 months during the 31-month period that followed the collection of the static foot measurements.

### 2.2 Foot Posture Index (FPI-6)

The FPI-6 assesses 6 characteristics across 3 different views of the foot, and assigns a numerical score to each characteristic. Each criterion is scored on a 5 point scale (-2 to +2), with negative numbers indicating a supinated posture and positive numbers indicating a pronated posture. The assessment typically takes less than 1 minute to complete and requires no equipment. The FPI-6 composite score ranges from -12 to +12. The composite score is used to categorize foot type as highly supinated (-12 to -1), supinated (0 to +1), normal (+2 to +5), pronated (+6 to +7), or highly pronated (+8 to +12) based upon established cut-off scores.[40, 41, 49]

### 2.3 Injury Data Acquisition

The Department of Defense Medical Metrics (M2) database contains all service members' and dependents' medical records. Records of each participant's musculoskeletal medical complaints with International Statistical Classification of Disease (ICD-9) codes between 700-999 were requested from the M2 database. Subjects were considered injured if they had at least one lumbopelvic or lower extremity musculoskeletal ICD-9 code within the 31-month study period. The medical costs, relative value units (RVUs), and number of visits associated with these injuries were also collected. RVUs provide a measure of medical complexity associated with the healthcare visit. The injuries and associated healthcare information were then organized into the following regions for analysis: lumbosacral, pelvis/hip/thigh, knee, leg, ankle, and foot.

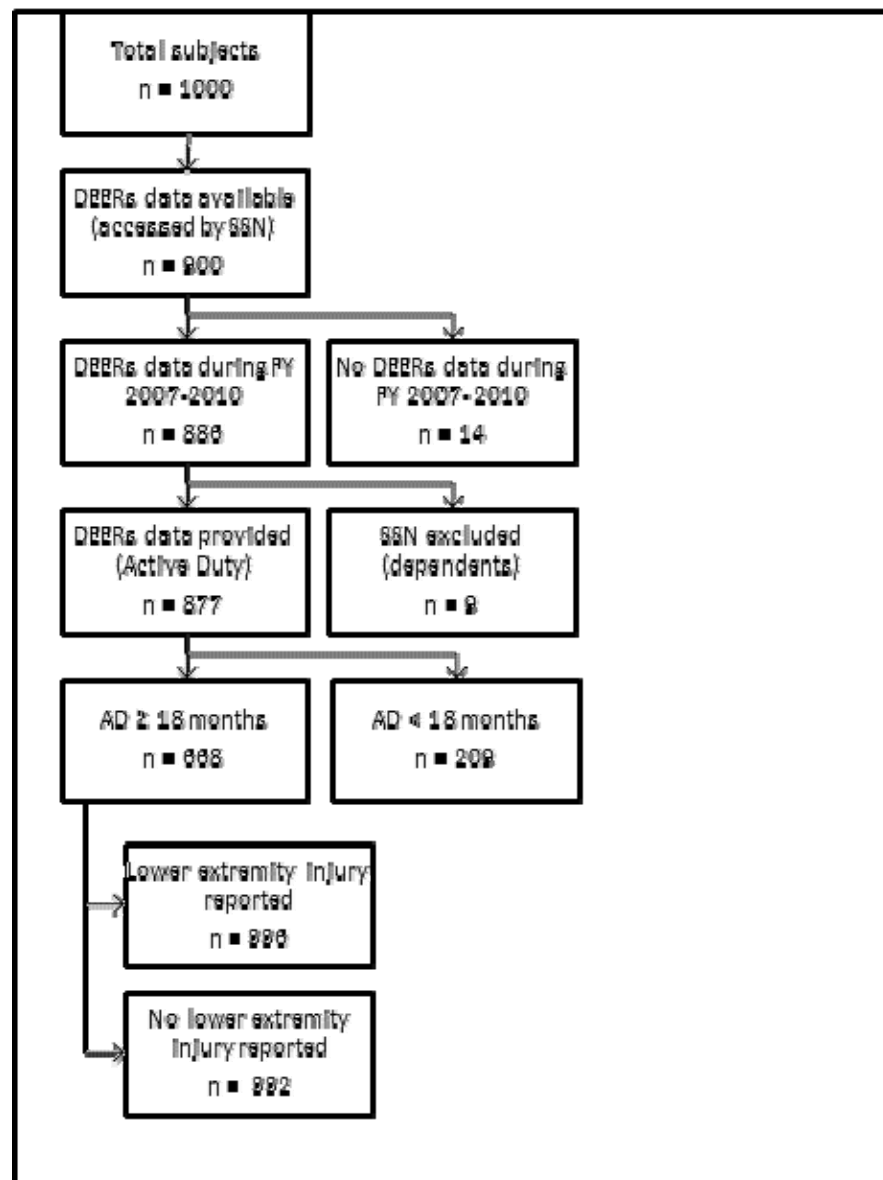
### 2.4 Statistical Analysis

Chi-Square and Mantel-Haenszel analyses were utilized to identify injury rates statistically different from that of the normal foot type. Univariate ANOVA was performed to assess associations between medical cost and foot type. ANCOVAs were also performed to demonstrate any significant differences adjusting for participants' BMI and/or age. Secondary analyses were performed using post hoc ANOVAs to determine which specific foot types were associated with increased cost, healthcare visits, and RVUs. Statistical analyses were performed using SPSS version 15.0.

## 3.0 RESULTS

### 3.1 Subjects

Of the 1,000 subjects recruited for the FFAST study, 668 were eligible for this analysis based on being an active duty service member that was eligible for military medical care at least 18 months from the date of study enrollment (Figure 1). Descriptive data on the subjects enrolled in this analysis are provided in Table 1. The distribution of foot types according to the FPI-6 assessment are displayed in Figure 2. The numbers of participants in each foot category were: 59 (8.8%) Highly Supinated, 87 (13.0%) Supinated, 362 (54.2%) Normal, 104 (15.6%) Pronated, and 56 (8.4%) Highly Pronated.

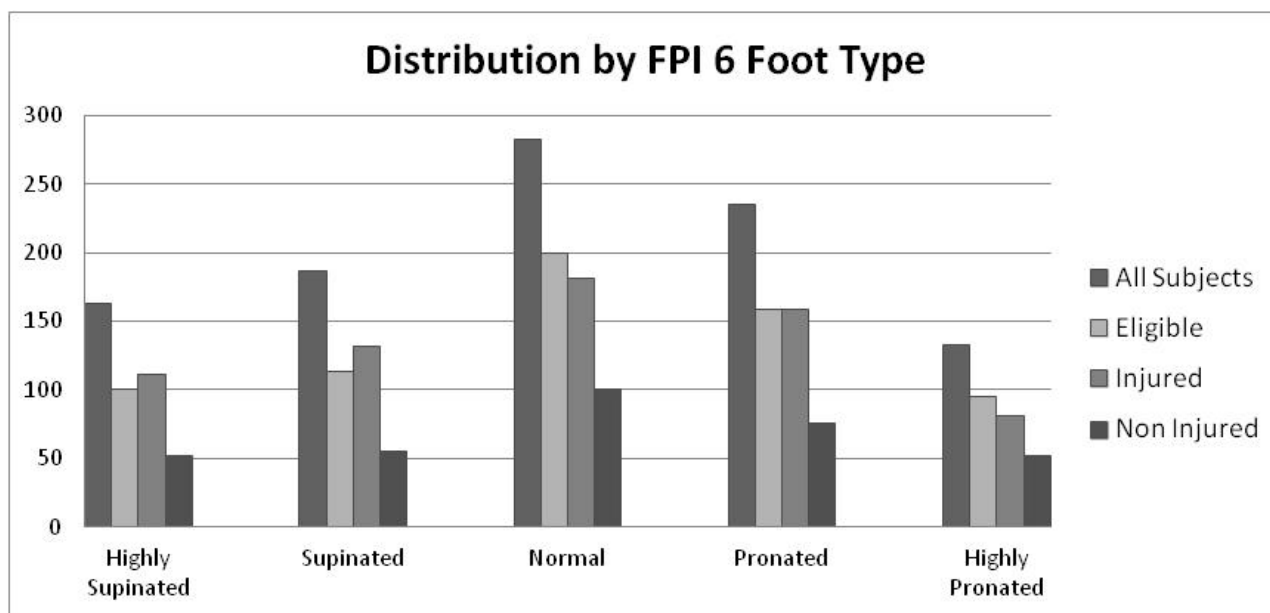


**Figure 1: Subject Recruitment:** Subjects from the larger trial were included in this study if they remained on active duty and were eligible for military healthcare for at least 18 months from the baseline assessment. Of the 668 Soldiers that met that definition, 336 (50.2%) reported a lumbopelvic or lower extremity injury.

*Abbreviations: AD: Active Duty, DEERS: Defense Enrollment Eligibility Reporting System, SSN: Social Security Number*

**Table 1: Subject characteristics. Values are mean (standard deviation)**

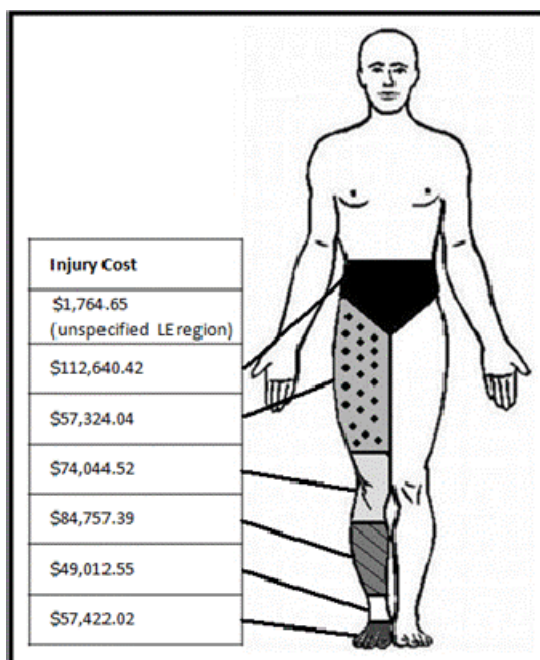
	N	Age (SD) years	BMI (SD) kg/m <sup>2</sup>	Height (SD) cm	Weight (SD) kg	% Female
<b>All subjects</b>	1000	30.6 (8.0)	26.2 (3.7)	171.1 (9.3)	77.0 (14.7)	43.4
<b>Eligible</b>	668	30.0 (7.4)	25.8 (3.3)	171.6 (9.4)	76.4 (14.2)	49.3
<b>Injured</b>	336	30.3 (7.5)	26.1 (3.4)	171.6 (9.2)	77.3 (14.4)	49.6
<b>Non-Injured</b>	664	30.9(8.3)	26.2 (3.8)	170.8 (9.3)	76.8 (14.9)	44



**Figure 2: Distribution of Foot Postures based on the FPI-6 Assessment**

## 3.2 Injury Data

Three hundred and thirty six (50.3%) participants sought medical care for lower extremity injuries during the study period, totalling 2,112 medical visits and a cost of \$436,965. Two hundred and forty three (36.4%) participants sought care for injuries at or distal to the knee. Cost and distribution of injuries are provided in Figure 3. The relative distribution of subjects that were injured was similar to the relative distribution of subjects eligible for this analysis (Table 2). There was a greater rate of knee injuries for those with a highly pronated foot type ( $p = 0.017$ ) or those with a pronated or highly pronated foot type ( $p = 0.011$ ) compared to those with normal foot type. Participants with the FPI-6 highly pronated foot type had a significantly higher rate of injury at the knee (highly pronated  $p = 0.017$ ) compared to participants with the normal foot type.



**Figure 3: Total Cost of Injuries Associated with Body Regions**

**Table 2: FPI-6 foot type distribution**

	All Subjects n (%)	Eligible n (%)	Injured n (%)
Highly Supinated	98 (9.8%)	59 (8.8%)	29 (8.6%)
Supinated	143 (14.3%)	87 (13.0%)	48 (14.3%)
Normal	527 (52.7%)	362 (54.2%)	173 (51.5%)
Pronated	158 (15.8%)	104 (15.6%)	57 (17.0%)
Highly Pronated	74 (7.4%)	56 (8.4%)	29 (8.6%)
Total (n)	1000	668	336

The medical cost of injuries from the knee distally varied based on foot type ( $p < 0.05$ ). Specifically, those with highly pronated feet incurred more medical costs for their injuries compared to those with a normal or supinated foot type ( $p = 0.008$ ). Pronated feet also resulted in greater medical costs for leg injuries compared to those with supinated feet ( $p = 0.03$ ). Highly pronated feet also resulted in greater medical costs for foot injuries compared to those with pronated or normal feet ( $p = 0.005$ ; Figure 4). No differences in analysis were noted

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when the analysis was run using an ANCOVA controlling for BMI or age. Secondary analyses demonstrated that participants with pronated foot type incurred increased relative value units (RVUs) for leg injuries ( $p = 0.02$ ) when compared to those with normal foot type. Additionally, subjects with highly pronated feet had significantly higher numbers of healthcare visits for injuries knee and distal ( $p = 0.02$ ) and leg injuries ( $p = 0.003$ ) than those with either normal or supinated foot types.

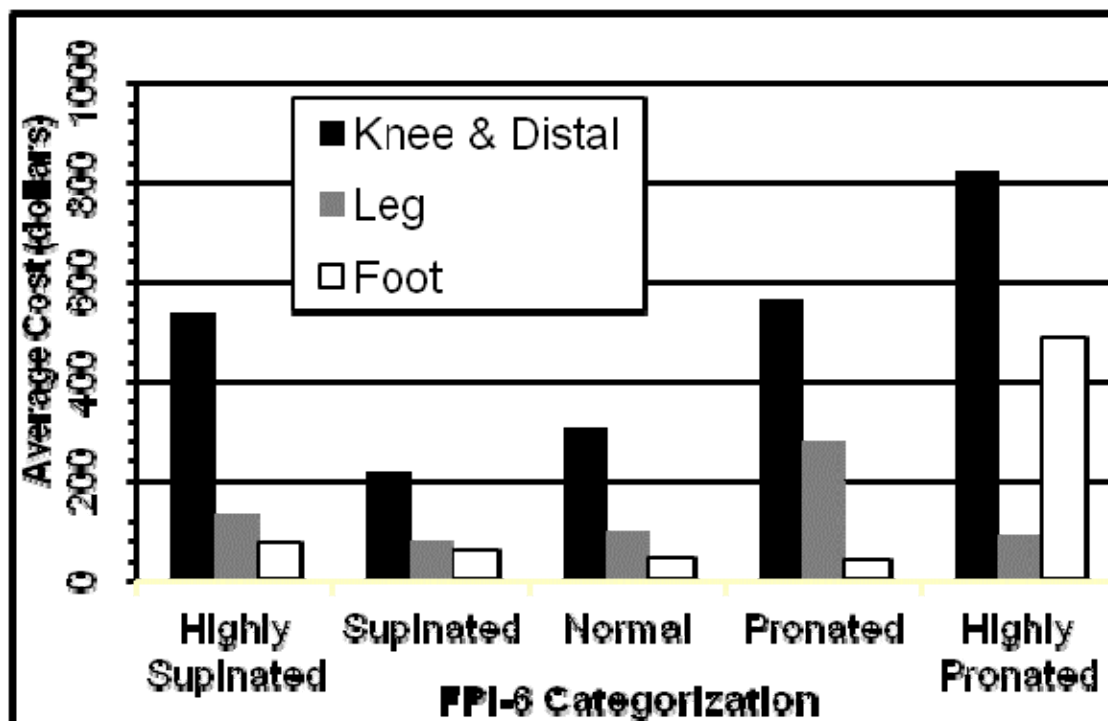


Figure 4: Average cost (in dollars) per injury according to FPI-6 foot classification.

## 4.0 DISCUSSION

Individuals with pronated feet resulted in significantly more healthcare visits with greater medical complexity which resulted in higher healthcare costs for injuries at or below the knee. Although previous researchers have demonstrated relationships between individuals with either low arched feet or those that excessively pronate with greater risk for medial tibial stress syndrome,[36, 38] knee pain,[33] and soft tissue overuse injuries along the medial aspect of the lower extremity [20, 22, 26, 38], scant evidence exists that associates foot type with healthcare utilization and costs. This study adds to the current body of knowledge by demonstrating that those with pronated feet resulted in more costly injuries than those with normal or supinated feet.

However, the musculoskeletal injury rates were similar between participants with pronated (53.8%), supinated (52.7%), and normal (47.8%) foot types. This is in conflict with prior literature that suggests extremes of foot type have a higher injury rate than those with a normal foot type.[26] For example, Kaufman et al [27] determined that individuals with a high or low arched foot types were twice as likely to develop a lower extremity stress fracture as those with a normal foot type. Differences in injury reporting

mechanism (self-report versus healthcare utilization) could account for some of these differences; more research is needed.

Although individuals with highly supinated feet appeared to have greater averaged costs compared to those with normal feet for injuries at the knee and below (Figure 4); these differences were not statistically significant. Our study did not find significantly increased healthcare utilization for those with supinated or highly supinated feet. This is in contrast to prior studies that have demonstrated that individuals with rigid, high arched feet may be at greater risk for sustaining bony ankle injuries,[26] stress fractures,[29-32] anterior knee pain,[33] and general overuse injuries or injuries involving the lateral structures of the lower extremity.[20, 22, 26, 34, 35, 37] The original sample (n = 1,000) utilized in this study had relatively few individuals with supinated or highly supinated feet as defined by the original FPI-6.[50] Definitions for the FPI-6 utilized in this study were determined based on a normative distribution of FPI-6 values. Future research utilizing larger sample sizes that specifically recruit individuals with highly supinated feet should explore this discrepancy further.

Regardless of foot type, the cost of lower extremity musculoskeletal in this sample of 668 Soldiers was substantial (\$436,966) over the 31 month period, with approximately 50% of all service members seeking healthcare for a lower extremity musculoskeletal injury. Assuming these results are generalizable to the active duty population, the cost for injuries from the knee and below would be \$221,155,500. It has been estimated that 20-50% of these injuries may be preventable.[10] Injury prevention programs with even a modest 5% reduction in injury rates could save the over \$11 million annually.

Several limitations exist in this study. Although the original sample size was 1,000, only 668 subjects remained eligible for military healthcare benefits during the duration of the study. When this sample was analyzed based on FPI-6 categories and injuries per body region; the sample size in some of the cells was relatively low. Additionally, the data analyzed in this study was based on available M2 data. Healthcare occurring at the unit-level that did not require a licensed healthcare provider was not analyzed. The impact of this is expected to be minimal as the goal of the study was to focus on injuries that resulted in healthcare utilization. In addition to healthcare utilization, future studies should assess the relationship between foot type and the incidence and mechanism of injury in larger samples. Additionally, the FPI-6 is an efficient screening tool to assess foot type that can be performed without equipment in 1-2 minutes, and thus can easily be performed in a clinic or in a group setting as part of an injury screening protocol. Risk mitigation strategies should be explored to help decrease both incidence and cost of lower extremity injuries.

## 5.0 CONCLUSION

Lower extremity musculoskeletal injuries are a huge burden on the military healthcare system. Pronated feet, as assessed by the FPI-6, were associated with significantly higher healthcare utilization and costs for injuries from the knee to the foot. Correctly identifying individuals at increased risk of higher healthcare utilization and costs from lower extremity musculoskeletal injuries provides opportunities to explore primary, secondary, and tertiary prevention strategies to mitigate that risk. Future research should determine if correctly identifying people with foot types susceptible to severe lower extremity MSI could help reduce future injuries and injury-related costs.

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